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The oldest rocks:
The Western Australian connection

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Abstract

The discovery of ancient fragments of the Earth's crust has provided new evidence to our understanding of the early history of the Earth. One of the earliest measurements of the age of terrestrial materials using the newly discovered radioactive decay of U to Pb was carried out by a Western Australian scientist, E S Simpson, in the first decade of the 20th century. Probably motivated by a visit to Perth by F Soddy in 1904, Simpson measured the age of a Western Australian U-rich mineral by the U-He method. Simpson's work largely went unnoticed until L R Cotton calculated the U-Pb ages from four U-rich samples analysed by Simpson. One of these ages was subsequently published by A Holmes, and this led to the belief that Western Australia was the location of the world's oldest rocks. In 1950, M Oliphant encouraged physicists at the University of Western Australia to build a mass spectrometer to measure the age of these old rocks. Subsequently P M Jeffery established a geochronological laboratory in which the U-Pb, Rb-Sr and K-Ar methods were developed, and the discovery of the "whole rock" Rb-Sr technique earned the laboratory an international reputation. In 1981, evidence of old banded gneisses (3550 Ma) was found at Mount Narryer, in Western Australia, and subsequently zircons of approximate age 4200 Ma were found at Jack Hills in the N-W corner of the Yilgarn Craton, 70 km north of Mount Narryer. In 2001, zircons up to 4400 Ma in age were discovered in the Jack Hills region, and this has led to a re-examination of our understanding of the early history of the Earth. These discoveries would not have been possible without the development of the Sensitive High Resolution Ion Micro Probe mass spectrometer (SHRIMP). This instrument revolutionised the science of geochronology by permitting the *in situ* microanalysis of U-Pb ages in zircons and other U- and/or Th- bearing minerals.

Keywords: geochronology, Jack Hills, Mount Narryer, rubidium-strontium, SHRIMP, uranium-lead, zircon

About this time, Rutherford, walking in the Campus with a small black rock in his hand, met the Professor of Geology: "Adams," he said, "how old is the Earth supposed to be?" The answer was that the various methods led to an estimate of 100 million years. "I know," said Rutherford quietly, "that this piece of pitchblende is 700 million years old." This was the first occasion when so large a value was given, based too on evidence of a reliable character: for Rutherford had determined the amount of uranium and radium in the rock, calculated the annual output of alpha particles, was confident that these were helium, measured the amount of helium in the rock and by division found the period during which the rock had existed in a compacted form. He was the pioneer in this method and his large value surprised and delighted both geologists and biologists (Eve 1939).

Introduction

The recent discovery in the Yilgarn Craton (Fig 1) of zircon grains which crystallised within the Earth's crust more than 4 Ga ago (Mojzsis *et al.* 2001; Wilde *et al.* 2001), may appear to reflect the simple confirmation of a belief, widely held through much of the 20th century, that the Earth's oldest rocks occur in Western Australia (Jeffery 1976). However, the connection between these recent papers and that long-standing belief is neither direct nor simple. The ages of the >4 Ga zircons from the Yilgarn Craton were determined using an advanced mass spectrometer (SHRIMP) designed and built in Australia (Compston 1996). The idea that the oldest rocks on Earth occurred in Western Australia had its origin in chemical analyses made by E S Simpson (Simpson 1910, 1911, 1912, 1919) of radioactive minerals from the Pilbara Craton, some 700 km to the north of the Yilgarn Craton location (Fig 1), and of uncertain geological relationship to it. A stimulus for Simpson's initiative was probably a visit to Perth in 1904 by F Soddy, an English chemist who had worked closely with E Rutherford in Canada on developments in radioactive decay, and was therefore aware of Rutherford's seminal realisation (Rutherford 1906) that the ages of radioactive minerals could be measured by determining the relative amounts of parent element and daughter product within them. Simpson's results made little impact at first, but Cotton (1926) and later Holmes (1927) and Holmes & Lawson (1927) revived interest in them. In particular the publications by Holmes brought the age and significance of the Pilbara minerals to the attention of the international geological

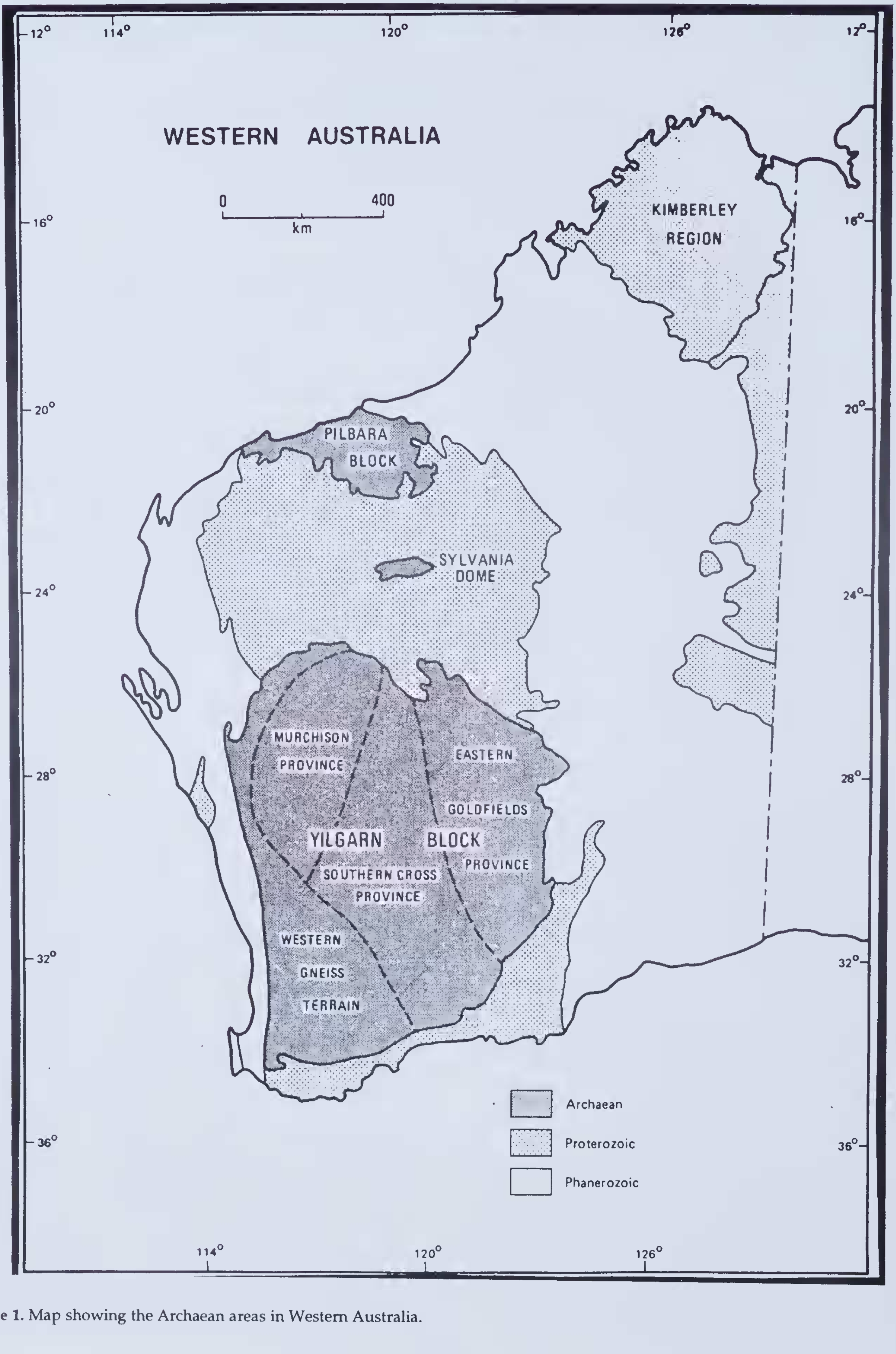

Figure 1. Map showing the Archaean areas in Western Australia.

community, and established Western Australia as the place where the oldest minerals occurred.

Other events flowing from that early work, and particularly from worldwide awareness of it, later led to a strong interest within Western Australia in the determination of rock and mineral ages using physical methods based on mass spectrometry, including SHRIMP. We believe that these events, and the serendipitous way in which they interacted to provide both the material and conceptual infrastructure for the recent Yilgarn Craton discoveries, provide a microcosm of scientific progress of sufficient interest to be worth recording. Our purpose in this paper is to provide such a record by summarizing the relevant events in greater detail.

Frederick Soddy's visit to Western Australia

The concept of time has never ceased to intrigue those who have thought about it. In particular, the age of the Earth has been studied by scientists over the centuries. Lord Kelvin estimated the age of the Earth by heat flow, George Darwin by tidal interactions, Edmund Halley from the saltiness of the oceans, and Charles Walcott by the accumulation of sediments. However, none of these "clocks" was particularly accurate and the physicist, Kelvin, fell into disrepute with geologists because his estimated age of 10 Ma, which he obtained by examining the cooling of the Earth from a molten body, was far too short as compared to geological estimates. Unfortunately for Kelvin, radioactivity was unknown at that time.

The discovery of radioactivity by H Becquerel in 1896, coupled with M & P Curie's demonstration that radioactive atoms transmute into atoms at predetermined and essentially immutable rates, provided the basis for a new clock to measure geological time. In 1902, two scientists at McGill University in Canada, the New Zealand physicist Rutherford, and Soddy, investigated the radioactive decay of U and showed that it decayed to the end-product Pb and also produced He from the alpha particles emitted in the decay scheme. In 1905, in the Silliman lectures at Yale University, Rutherford suggested the possibility of using radioactivity as a geological timekeeper on the basis that if one could measure either of the decay products He or Pb, then one could measure geological time by this nuclear clock (Rutherford 1906).

The Western Australian connection with the Earth's oldest rocks began in most unusual circumstances. In 1904, Soddy, a leader in this new field of radioactivity, visited Western Australia to give a series of lectures on recent developments in science. Soddy had left McGill University in 1903 to join W Ramsay at University College, London, and had demonstrated that radon and He were produced in radioactive decay. In the English summer of 1904, Soddy was persuaded to make the long sea voyage to Australia by a group of Western Australians, under the chairmanship of J W Hackett, who was trying to arouse public interest in the need to establish a University in Western Australia. At that time secondary school students in Western Australia sat for the South Australian Public Examination, and a few Perth Technical College students sat science degree examinations at the University of Adelaide under an arrangement established by W H Bragg, who was Head of the Department of Physics at that University.

Soddy gave a number of lectures in Perth (6), Fremantle (3), Kalgoorlie (2) and in five other country towns (1 each). His lectures covered "electricity, x-rays, radioactivity, the structure of matter and the evolution of the universe" (Jenkin 1985). Soddy was in great demand as a public lecturer in London, in part because of the demonstrations he used to illustrate his lectures. He brought an extensive array of equipment to Perth and his lectures were well attended and much appreciated. In fact, Soddy's first lecture in Perth was booked out, and hundreds of people were unable to gain admission. It is of interest to note that Soddy sold his equipment to Perth Technical College at the end of his lecture tour and some of that equipment is now on display in the Department of Applied Physics at Curtin University. Jenkin (1985) reports that Soddy's visit helped to hasten the establishment of the University of Western Australia.

The work of E S Simpson

An interesting but almost completely unknown aspect of the geochronology of Western Australian geological specimens emerged in 1910 when E S Simpson, then Chemist and Assayer of the Geological Survey of Western Australia, measured the age of a U-rich mineral, which he named pilbarite, from a pegmatite at Wodgina in the Pilbara Craton. One might assume that Simpson was influenced in this endeavour by Soddy's visit, as he measured the amount of He released from the pilbarite as well as the U content, using chemical techniques, and thereby calculated an age of 13 Ma (Simpson 1910, 1911).

The only means available at that time for measuring He and Pb were chemical techniques, and both suffered serious shortcomings. Helium, which is a gas, leaked out of U-rich ores because of radiation damage and weathering effects. Thus, calculated ages were underestimates. On the other hand, the measurement of the quantity of Pb could not distinguish radiogenic Pb from primordial Pb, and could not identify the source of the radiogenic Pb. Simpson understood the limitations of the U-He methodology he had adopted, because he pointed out that the mineral he had used was a secondary weathering product and had probably lost radiogenic He (Simpson 1910, 1911). At about the same time, Simpson also fully analysed two associated U minerals from the same pegmatite, which he identified as mackintoshite and thorogummite, parental to the pilbarite. An intriguing question then presents itself as to why Simpson failed to calculate the ages of all three minerals from the amount of Pb present. He had determined this, and had specifically commented on its derivation by radioactive decay. Simpson was also familiar with the work of Boltwood, who had calculated radiometric ages based on chemically-determined Pb/U ratios, for he mentions him by name (Simpson 1912).

Whatever the reason for this puzzling omission, fifteen years went by before Cotton, Professor of Geology at the University of Sydney, used Simpson's analytical results to calculate chemical U-Pb ages for these minerals and also for fergusonite from another Pilbara pegmatite at Cooglegong, an analysis of which had by then been published by Simpson (1919). Cotton (1926) calculated ages of 620, 1475, 1460 and 3840 Ma respectively for fergusonite, mackintoshite, thorogummite, and pilbarite, and took account of the Pb contribution by Th. Holmes & Lawson (1927) independently revised Cotton's calculations, and the inclusion of the age of "mackintoshite, etc" as 1260 Ma in Holmes' (1927) popular book "The Age of the Earth", in which it was the oldest age recorded, placed the significance of Simpson's analytical work before a wide audience. It now appears that this age is too low by a factor of at least two, and this makes it even more ironic that it was probably largely due to Holmes' book that a widespread belief arose that the Precambrian of Western Australia contained the most ancient rocks of the Earth's crust (de Laeter & Trendall 1979).

Isotopic method of geochronology

The "chemical" method of age determinations, beset as it was with fundamental flaws, was of short-lived duration, since in 1912 J J Thomson at the Cavendish Laboratory in Cambridge University laid the foundation of "physical" geochronology by his discovery of isotopes. F W Aston, using a mass spectrometer of his own design, was able to show that a U-rich sample of bröggerite had at least three isotopes of Pb and that the sample was enriched in ^{206}Pb, a decay product of ^{238}U. This enabled an age of 909 Ma to be calculated for the bröggerite sample (Aston 1929). A companion paper by Rutherford gave an estimate of the age of the Earth as 3.4 Ga (Rutherford 1929).

This experiment by Aston (1929) heralded a new era in geochronology, an era based on isotopic rather than elemental measurements. Since that time the mass spectrometer has been an indispensable tool for every geochronologist, a veritable "time machine" that enables us to explore the past with a variety of radioactive decay systems with ever-increasing accuracy. A significant step in validating the isotopic method of age determinations was provided by A O Nier, who demonstrated that the isotopic abundances of Pb samples varied considerably, depending on the chemical composition and age of the ores (Nier 1938). Nier showed that U-rich ores gave Pb enriched in ^{206}Pb and ^{207}Pb, whereas Pb derived from Th-rich ores were enriched in ^{208}Pb. The only Pb isotope that is unaffected by radioactive decay is ^{204}Pb, because it is not the end-product of a radioactive parent and therefore represents primordial Pb that was inherited by the ore at its time of formation. ^{204}Pb can, therefore, be used to correct for primordial or "common" Pb contamination for the isotopes $^{206, 207, 208}$Pb. Using this technique, Nier *et al.* (1941) calculated a U-Pb age for a sample of monazite from Manitoba, Canada, of 2570 ± 70 Ma.

At the end of World War II, when non-military scientific research began its phenomenal growth, geochronology was poised to revolutionise our knowledge of geological events. One ingredient, however, was missing. Although the theoretical concepts of radioactive dating had been developed, no instrument existed outside physics research laboratories that would enable geologists to exploit the powerful new geochronological tools available to them. However, this situation was soon to be changed.

Until 1940, mass spectrometers were either sophisticated double focusing machines used primarily for measuring the atomic masses of nuclides, or large, complicated 180° machines that were difficult to build and operate successfully. However, in 1940 Nier described a distinctively different type of mass spectrometer that was destined to be the tool whereby geochronology could be exploited (Nier 1940). In 1947, using the extensive experience of building and using these mass spectrometers in the Manhattan Project during World War 11, and incorporating technological improvements that had occurred since 1940, Nier described a modified version of the 60° sector field instrument (Nier 1947). The importance of the 60° sector field instrument was that the elegance of its simple design enabled scientists other than physicists to utilise the power of isotopes in biology, chemistry, and geology, and this development was achieved against the prevailing opinion of the day, as expressed by Aston who believed that mass spectrometry would die away as an active research field (Svec 1985).

Geochronology in Perth

A number of geochronology laboratories were established in the 1950's based on the sector field mass spectrometer. These laboratories were often a cooperative arrangement between geologists and physicists, because mass spectrometers of that era were primitive instruments as compared to modern mass spectrometers and required much care and maintenance to keep them in an operating condition. This was certainly the case in Western Australia. In 1950, on his way to take up an appointment at the Australian National University (ANU), Professor (later Sir) Marcus Oliphant visited the Physics Department of the University of Western Australia (UWA) and spoke of the need for an Australian research program in geochronology, particularly in view of the widespread belief that this continent contained the Earth's oldest rocks (Jeffery 1976). Oliphant had worked with Rutherford in Cambridge, and was familiar with the physical techniques used in geochronology.

As a result, two staff members of the Physics Department at UWA, P M Jeffery and A H Morton, terminated the construction of a small accelerator and began instead to build a mass spectrometer, intended ultimately for a continuing geochronological program. Jeffery (1976) has given a graphic account of the difficulties involved. The instrument was first operated in late 1952, but its performance was unsatisfactory, and during 1953 it was decided to abandon the project unless more financial support could be found (Fig 2). Fortunately, a grant became available from the Carnegie Institute of Washington, sufficient not only to bring the home-made instrument into effective operation but also to provide a second, new, Nier-type mass spectrometer. It was with this second instrument that the first isotopic U-Pb age was obtained from a Western Australian mineral. The tanteuxenite analysed came from a pegmatite at Woodstock, again in the Pilbara Craton, and yielded a maximum age of 2790 ± 25 Ma (Greenhalgh & Jeffery 1959).

Figure 2. The original mass spectrometer flight tube used by P M Jeffery at UWA in the early 1950s. Shown in the photograph are three individuals who were involved with this equipment (left to right): J Budge (technician), W Compston and J R de Laeter (research students).

Jeffery and his team also established the K-Ar and Rb-Sr methods at Perth in the 1950s, and a seminal paper by Wilson *et al.* (1960) listed 36 Rb-Sr ages, 16 K-Ar ages and 21 U-Pb ages that resulted from this geochronological research. The first systematic attempt to relate this age data to the tectonic evolution of Western Australia was given in this paper (Wilson *et al.* 1960).

It is worth noting that Jeffery, in collaboration with W Compston who had been a doctoral student with Jeffery but now a staff member of the Physics Department at the UWA, proposed a "whole rock" Rb-Sr model. This represented an important advance in the interpretation of discordant Rb-Sr ages and established the Rb-Sr technique as a powerful geochronological tool (Compston & Jeffery 1959).

Unfortunately, by the end of the 1950s geochronological research had ended in Perth, but was established in the Department of Geophysics at the Australian National University (ANU). Compston was invited to lead the geochronology program and moved to the ANU in 1961. Geochronology was re-established in Perth in 1968, when another of Jeffery's former physics students (de Laeter) was appointed to the Department of Applied Physics at the Western Australian Institute of Technology (WAIT). With encouragement from Compston, a pilot-scale program of Rb-Sr geochronology was established in conjunction with the Geological Survey of Western Australia (GSWA). The Director of GSWA, J H Lord, accepted a recommendation from its petrologist (Trendall), that this cooperative work had considerable significant potential to advance the geological understanding of the Western Australian Precambrian.

The success of the early Rb-Sr work led to the extension of the geochronological program to include the Sm-Nd and U-Pb techniques, and the 60° sector field mass spectrometer used was progressively modified as technological advances in vacuum equipment, electronics and data handling facilities occurred. The cooperative program finally led to the appointment of a specialist geochronologist (D R Nelson), within the GSWA. In the mid-1970s, staff from UWA joined in the existing geochronology program, and clean-room facilities for U-Pb analyses were commissioned at that institution.

SHRIMP

As geochronology developed in many laboratories around the world, using an increasing number of radioactive decay schemes, the demand for improved mass spectrometric instrumentation led to a succession of technological advances in mass spectrometry. These advances enabled geochronology to reach a level of scientific sophistication of impressive dimensions. De Laeter (1998) has traced the development of geochronology in a mutually cooperative way with the development of mass spectrometry. Over the past 50 years or so technological advances have enabled the sector field instrument to meet most of the requirements of the various geochronological techniques that have been developed over this period of time.

During the past 25 years or so, however, radically new spectrometers have been developed. In terms of the Western Australian connection with the search for old terrestrial material, the most significant by far has been Secondary Ionisation Mass Spectrometry (SIMS). The ability to isotopically analyse minerals *in situ*, without the need of laborious chemical processing, in a mass spectrometer with high sensitivity and good resolution, has long been a goal for geochronologists. Furthermore, the ability to selectively analyse minerals without the inherent problems associated with whole rock analysis offers the opportunity of a quantum jump in the quality of geochronological information, thus opening up new frontiers of geological knowledge.

Compston and his colleagues at the ANU realised that a SIMS-type mass spectrometer would be required to achieve these geochronological objectives, incorporating an efficient ionisation source to provide the high sensitivity required for U-Pb analysis. This implied the need for a double focusing mass spectrometer with energy focusing to compensate for the large spread in energy possessed by the ions sputtered from a sample by

Figure 3. A photograph of SHRIMP II, located at Curtin University.

an ion bombardment source operated at a high accelerating voltage. The mass spectrometer would also need to possess high resolution to resolve interfering isobars in the vicinity of Pb and U, if effective U-Pb geochronology was to be carried out.

Compston (1996) has described the design, fabrication and operation of SHRIMP at the ANU. The success of SHRIMP I in the early 1980s led to the construction of a commercial version (SHRIMP II) in the late 1980s, and a consortium from Perth comprising Curtin University of Technology (formerly WAIT), the GSWA and UWA acquired a SHRIMP II in 1993 (Fig 3). The SHRIMP mass spectrometers at Canberra and Perth have been used extensively in analysing zircons and other U- or Th-bearing minerals in age determinations of rocks and minerals in Western Australia.

The Mount Narryer – Jack Hills Discoveries

The availability of a number of geochronological techniques was a crucial element in the search for the oldest rocks in the north-west portion of the Yilgarn Craton. The Yilgarn Craton is an ancient crustal block, one of the largest segments of Archaean crust in the world, and therefore of importance to studies of early crustal evolution. In 1981, a Rb-Sr age determination of banded gneisses near Mount Narryer yielded a whole rock isochron age of 3348 ± 43 Ma with an initial $^{87}Sr/^{86}Sr$ ratio of 0.7037 ± 0.0005 (de Laeter *et al.* 1981). These data indicated that the rocks had a prior crustal residence time of approximately 200 Ma to give a time of extraction of the granitic melts from the mantle of approximately 3550 Ma. The validity of this early Archaean age was supported by model Sm-Nd ages of 3510 Ma and 3630 Ma for two of the samples. These ages represented the oldest evolutionary sequence thus far identified in the Yilgarn Craton. The banded gneisses, (the Meeberrie Gneisses), were also subjected to U-Pb analysis to give a Pb-Pb age of 3357 ± 70 Ma, in close agreement with the original Rb-Sr age (de Laeter *et al.* 1985). This age was interpreted as resulting from metamorphic reworking of the primeval quartz-feldspathic material (de Laeter *et al.* 1981). Further Sm-Nd analysis of samples from the Meeberrie Gneiss gave T_{CHUR} ages of 3710 ± 30 Ma and 3620 ± 40 Ma confirming that the Western Gneiss Terrain is the oldest known major segment of sialic crust in the Yilgarn Craton.

Striking confirmation of the Mount Narryer results emerged from ion microprobe studies of the 3620 Ma Meeberrie gneiss sample carried out at the ANU (Compston *et al.* 1982). The analyses revealed that the youngest rims of several grains have a concordant U-Pb age of approximately 3300 Ma, whilst interior portions of zircons from the same suite give ages from 3690 Ma to 3560 Ma. These older ages have been interpreted as minimum estimates for the original magmatic ages of the xenocrystic cores.

U-Pb studies by the ion microprobe on detrital zircons from quartzite adjacent to the Meeberrie banded gneiss showed that most of them formed between 3500 and 3750 Ma ago, although some of them gave ages of about 3300 Ma (Froude *et al.* 1983). These ages suggest that the zircons may have been derived by erosion of the adjacent gneisses or their protoliths. In addition, Froude *et al.* (1983) reported the existence of four zircons from the same quartzite which have nearly concordant U-Pb ages between 4100 and 4200 Ma. These results suggest that pre-3800 Ma silica-saturated rocks were present in the Earth's crust.

The Jack Hills metasedimentary belt is a narrow curvilinear east to north-east trending belt approximately 70 km north-east of Mount Narryer. It is composed of minor metabasalts and substantial thicknesses of chert and banded iron formation interleaved with pelitic and psammitic metasediments. Detrital zircons from the Jack Hills metasedimentary belt analysed at the ANU using SHRIMP, revealed the oldest ages thus far determined. One zircon grain registered an age of 4276 ± 6 Ma, which is a minimum estimate for its original age (Compston & Pidgeon 1986). Sixteen other grains have similar ages to the zircon ages measured at Mount Narryer. One of the important features of the Jack Hills measurements has been that the frequency of occurrence of the old zircons (12 ± 5%), is some five times higher than at Mount Narryer.

Kober *et al.* (1989) reported the analyses of thirty zircon crystals from the Jack Hills metaconglomerate using the single zircon, direct evaporation, thermal ionization technique. Four of the thirty zircons gave ages in excess of 4000 Ma, confirming the microprobe analyses of Compston & Pidgeon (1986). Approximately 50% of the analysed zircons yielded an age of 3380 ± 20 Ma, whilst other crystals gave ages of 3300 Ma, 3440 Ma and 3570 Ma. As had been observed at Mount Narryer, some of the zircons demonstrated a more complex age structure with intergrowth of older mineral phases with younger domains.

However the exciting age determination of the 1980s is by no means the end of the investigation into the oldest rocks in Western Australia. Nelson *et al.* (2000) have described a zircon from a leucratic gneiss from the Narryer Terrane which records at least five high-grade thermal events at approximately 4186, 4140, 4005, 3978 and 3945 Ma, which may represent rapid tectonic reworking of siliceous fragments of the Earth's early crust by collision and amalgamation, or reworking by meteorite impacts. Later events are also recorded in this zircon, which can be related to known regional-scale tectonic events that affected the Narryer Terrane. This study demonstrates that the frontier of zircon geochronology is located within individual grains.

Then in 2001, two companion papers appeared (Wilde *et al.* 2001; Mojzsis *et al.* 2001), which have challenged our understanding of the early history of the Earth. A zircon crystal with an age of 4404 Ma was discovered at Jack Hills, Western Australia, making it the most ancient fragment of the Earth's crust ever identified (Wilde *et al.* 2001). The age determination was carried out with the SHRIMP at Curtin University. It is about 130 Ma older than any previously analysed material, and was formed approximately 150 Ma after the planet consolidated. Wilde *et al.* (2001) point out that the crystal has elevated oxygen isotope ratios suggesting a source rock that interacted with liquid water. This indicates that the Earth cooled much faster than previously thought and places constraints on the time that the Moon separated from the Earth. The crystal's chemistry is consistent with formation in a granitic rock whose precursor interacted with water, thus providing the earliest evidence of continents and oceans on Earth. In another study of zircons from Jack Hills (Mojzsis *et al.* 2001), a large range of oxygen isotope compositions (5.4-15.0 per mil) were measured in zircons older than 4000 Ma. Mojzsis *et al.* (2001) postulated that this large range in oxygen isotope ratios is evidence of re-working of the crust and the production of S-type granites, and for water near the earth's surface and the presence of a hydrosphere at 4300 Ma.

Conclusions

The evolution in geological thinking as a result of the discovery of ancient fragments of the Earth's crust is almost entirely due to developments in isotopic geochronology as an outcome of new and improved methods of mass spectrometric instrumentation. Although Western Australia is by no means the only geographic location where the search for old rocks has occurred, this State has nevertheless played an important role in this endeavour.

Probably as a result of the 1904 visit to Perth by Soddy, a Western Australian scientist measured the age of a U-rich ore by the U-He method in 1910 (Simpson 1910, 1911). Although Simpson's work was largely unnoticed, his age data were published in an international scientific journal by Cotton (1926), who recalculated Simpson's chemical analysis on four Western Australian minerals, using the U-Pb method. The republication of some of Simpson's age data in 1927 led to the widespread belief that the Precambrian of Western Australia contained the most ancient rocks in the Earth's crust (Holmes 1927).

It was this widely held belief that led Oliphant, in 1950, to suggest that a mass spectrometer be built in the Physics Department of the UWA to search for these ancient rocks. The geochronology laboratory established by Jeffery in the 1950s was an outstanding success, for it was not only the first mass spectrometry laboratory in Australia, but it provided the training ground for a number of young physicists, one of whom (Compston), was to play a unique role in isotope science research and in mass spectrometric innovation. The development of SHRIMP was the result of Compston's dedication and initiative and this instrument has revolutionised U-Pb geochronology using U- and /or Th-rich minerals.

Although the establishment of geochronology in Western Australia in the 1950s might appear to have been fortuitous, the infectious enthusiasm of Jeffery and the prior existence of instrumental skills within a Physics Department were basic ingredients for success. It was also significant that Precambrian granitic rocks with an age of about 2400 Ma which had been affected by a thermal overprint at about 520 Ma were available for study. It was the challenge of this situation that produced the Rb-Sr whole rock method, which in turn established the laboratory as an international leader in geochronology.

Furthermore, the presence of vast Archaean cratons in Western Australia virtually guaranteed that significant geochronological results would be forthcoming. Such results have emerged from the Mount Narryer – Jack Hills region over a period of some 20 years, commencing with the discovery of banded gneisses of approximate age 3550 Ma in 1981 (de Laeter *et al.* 1981), and culminating in the discovery of a 4404 Ma zircon in 2001 (Wilde *et al.* 2001).

The radioactive clocks, which are the key to our understanding of the chronology of the Earth, have progressively yielded their secrets as technological developments have enabled minute quantities of the radioactive elements and their daughter products to be measured with ever greater accuracy and precision. The development of SHRIMP has undoubtedly been of key importance in this work. There seems to be no reason to doubt that further refinements are possible as an ever-increasing number of chronometers are available singly or in combination to tackle the problems of Precambrian geology. The search for the oldest rocks in Western Australia continues after almost a century of effort built on the pioneering age determinations of Simpson.

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